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A Lagrangian study of globally emitted aviation NO_x and associated short-term O_3 radiative forcing effects

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The resilient growth of air travel demands a comprehensive understanding of the climate effects from aviation emissions. The current level of knowledge of the environmental repercussions of CO_2 emissions is considerably higher than that of non-CO_2 emissions, which includes nitrogen oxides (NO_x), sulfur oxides (SO_x), other aerosols like black carbon (BC), water vapor and contrails. Aircraft NO_x emissions not only possess a high degree of uncertainty because of the non-linearity of the NO_x – O_3 chemistry, but are also responsible for producing the second strongest net warming effect out of all non-CO_2 climate forcers from aviation, right after contrails [1]. This study employs global-scale simulations to characterize the transport patterns of nitrogen oxides and assess their climate effects across several regions (North America, South America, Africa, Eurasia and Australasia) from January to March and July to September in 2014. Radiative forcing effects from the short-term increase in O_3, which are triggered by NO_x emissions, are estimated. These emissions, which are introduced at a typical cruising altitude, are modelled as Lagrangian air parcels that are transported within the ECHAM5/MESSy Atmospheric Chemistry (EMAC) model [2]. In order to summarize the dynamical and radiative forcing characteristics of more than 10,000 simulated trajectories, a clustering approach with an adapted distance metric is applied. The method itself is an unsupervised machine learning algorithm, called QuickBundles [3], that is most commonly used in the field of neuroscience. A strong seasonal dependence is found for the contribution of NO_x emissions to O_3. In terms of residence times, NO_x emitted in Northern regions resides mainly in the upper mid-latitudes while those initiated in the South remain mostly in the Tropics. Due to pronounced zonal jets, the location of emission does not necessarily correspond to the region that will be most affected, i.e., an emission starting in N. America in July will induce the greatest warming in Europe.

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